Overview of the CASTNET Program

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Clean Air Markets Division

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http://www.epa.gov/castnet

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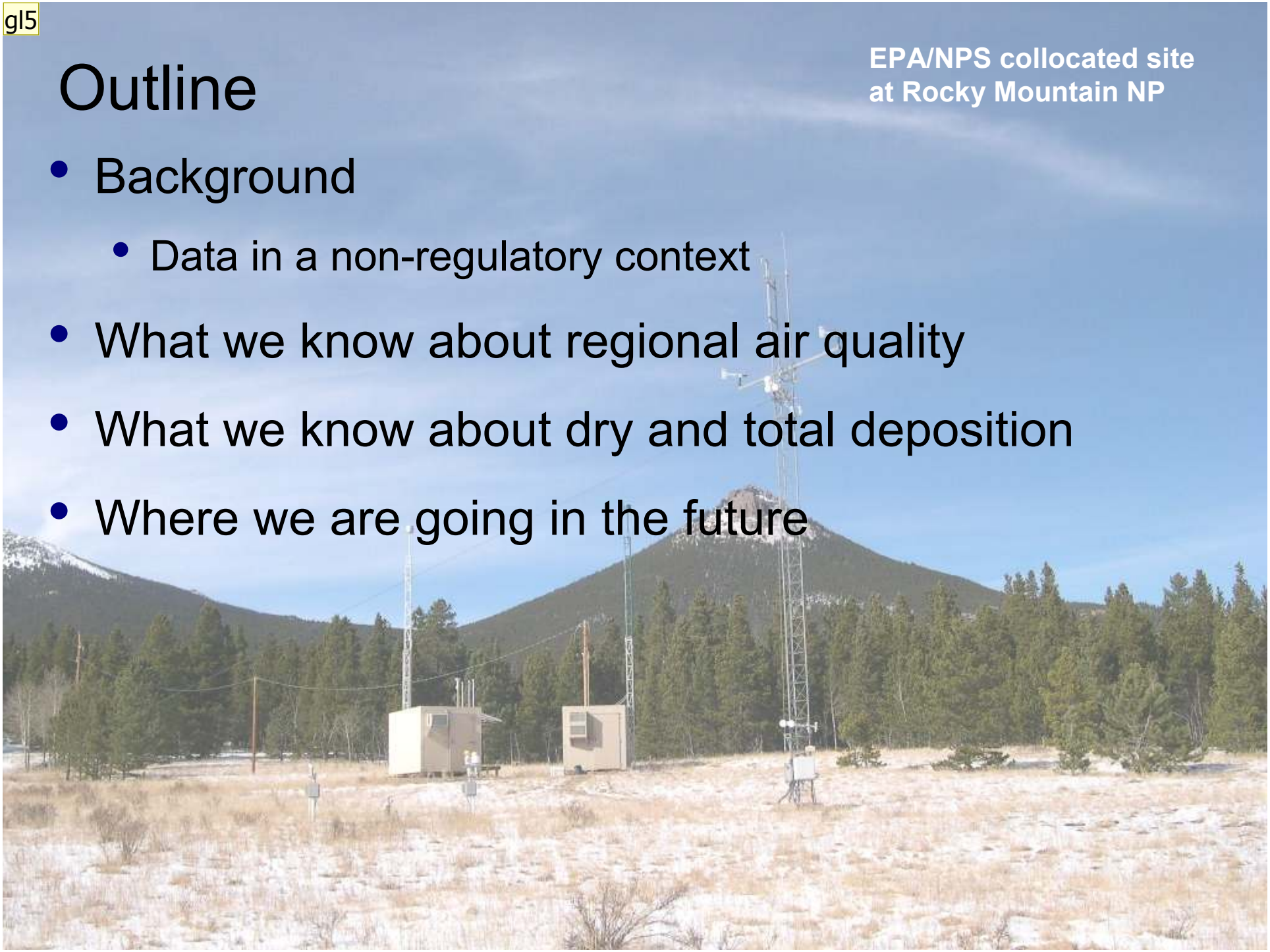
Outline

- Background
  - Data in a non-regulatory context
- What we know about regional air quality
- What we know about dry and total deposition
- Where we are going in the future



EPA/NPS collocated site
at Rocky Mountain NP

Slide 2

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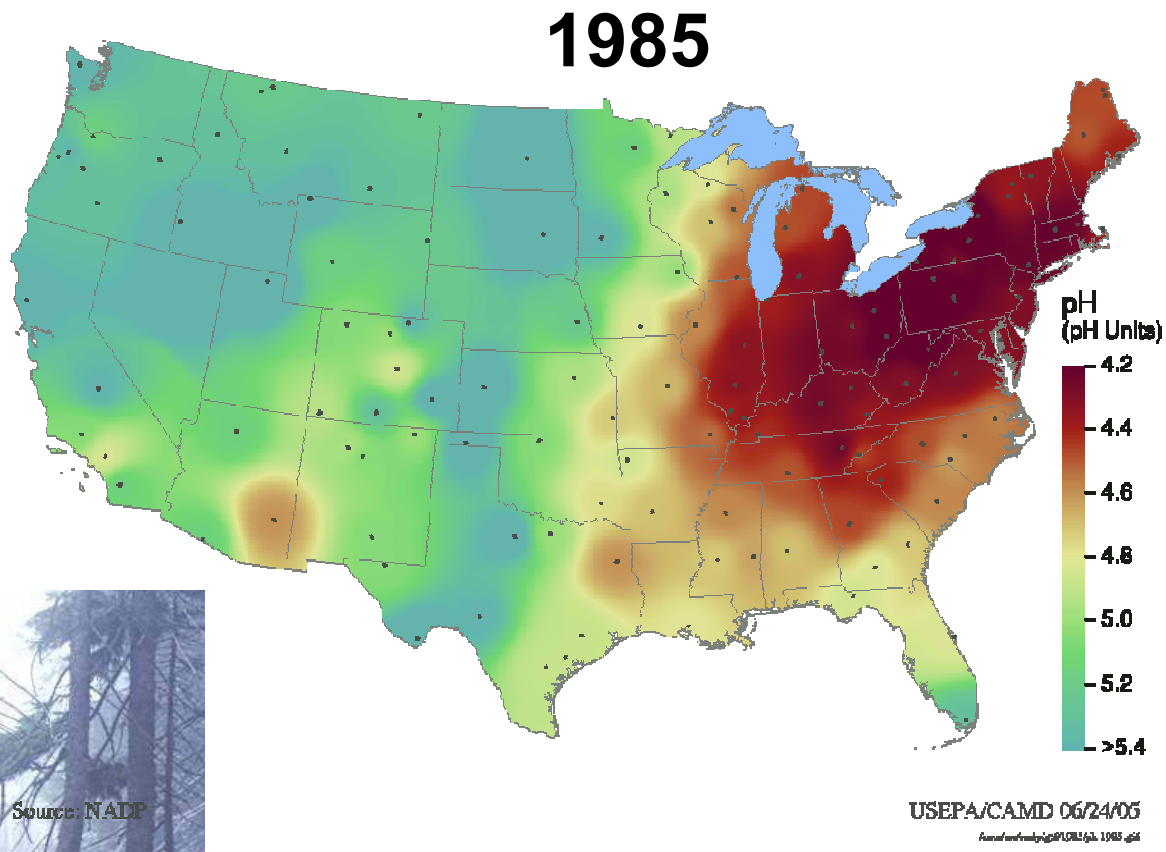
Why are we monitoring?
Science based
glear, 11/7/2006

The Problem: Acid Rain

CASTNET was established in the 1990 CAAA to provide accountability for emission reduction programs



Red spruce decline due to acid rain.
(Steffen Hauser/Oxford Scientific Films)

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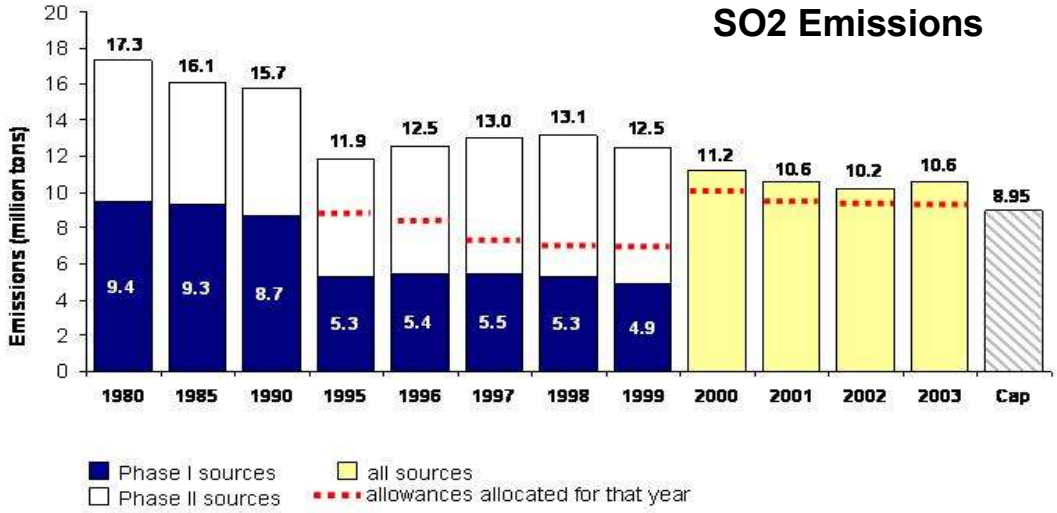
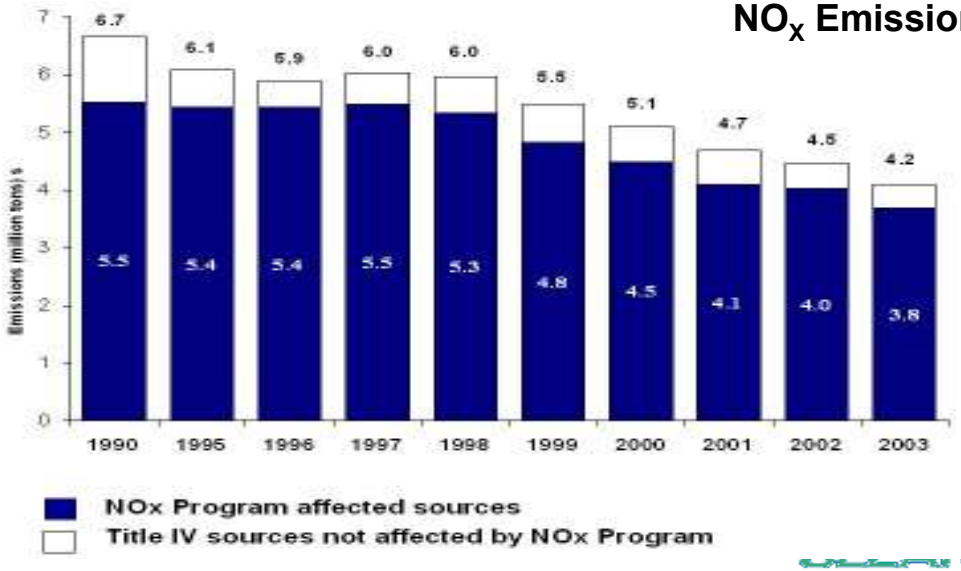
Emission Reductions under the Acid Rain Program

- Substantial reductions during Phase I and II of the Program
- Annual emissions fluctuations expected as sources close in on the cap
- Estimated costs ranged from $20B down to $5B
- Sources required to meet NOx emission *rates*; no emissions cap and no emissions trading

SO2 Emissions



NO_X Emissions



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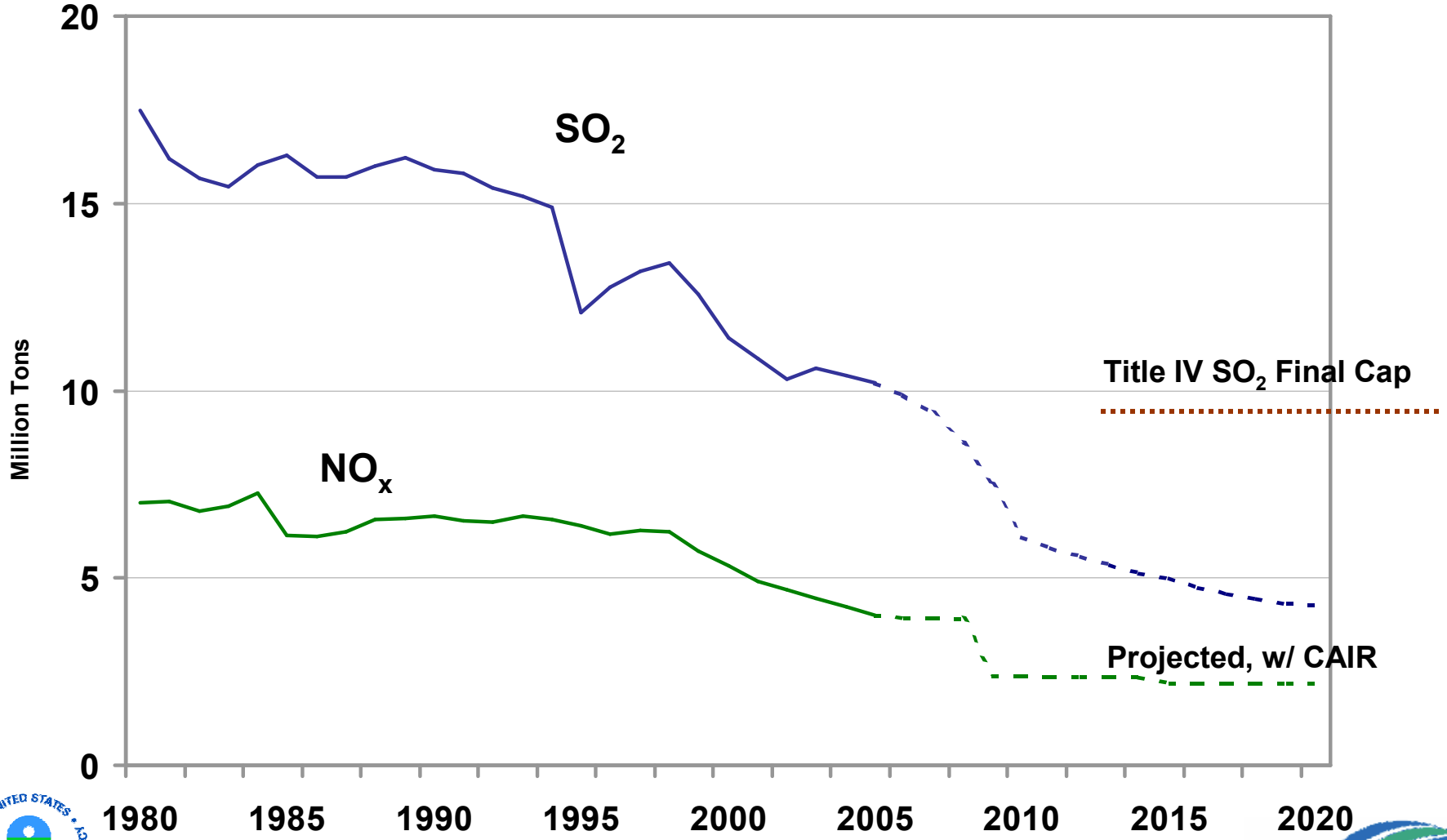
glear, 11/7/2006

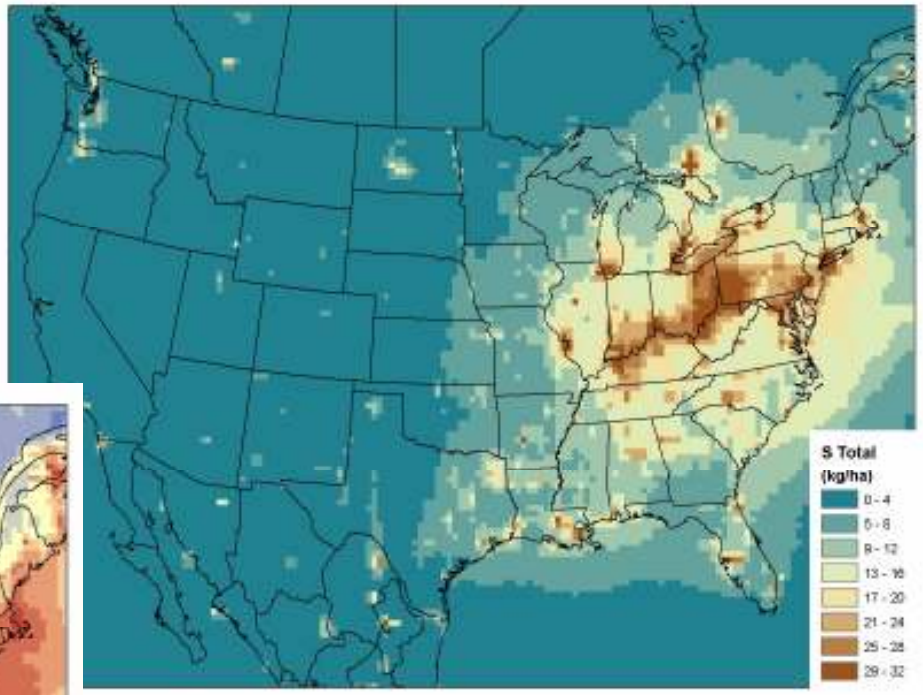
… and SO_2 and NO_x emissions from the power sector continue to be reduced



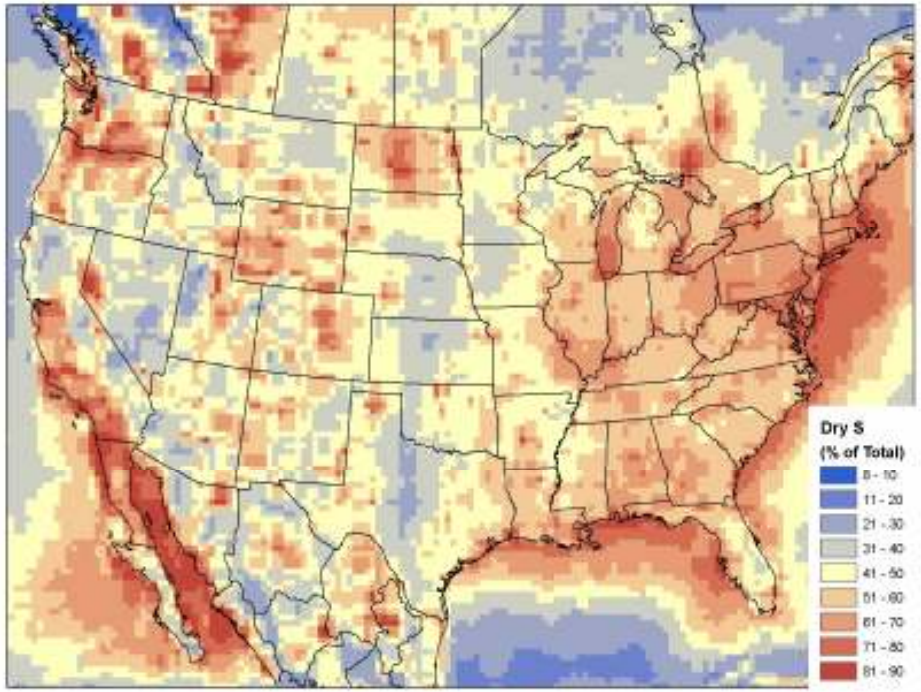
Source: EPA

How important is dry deposition?

Dry sulfur deposition is a major component of total deposition in many areas of the US



CMAQ output for total sulfur deposition (2001)



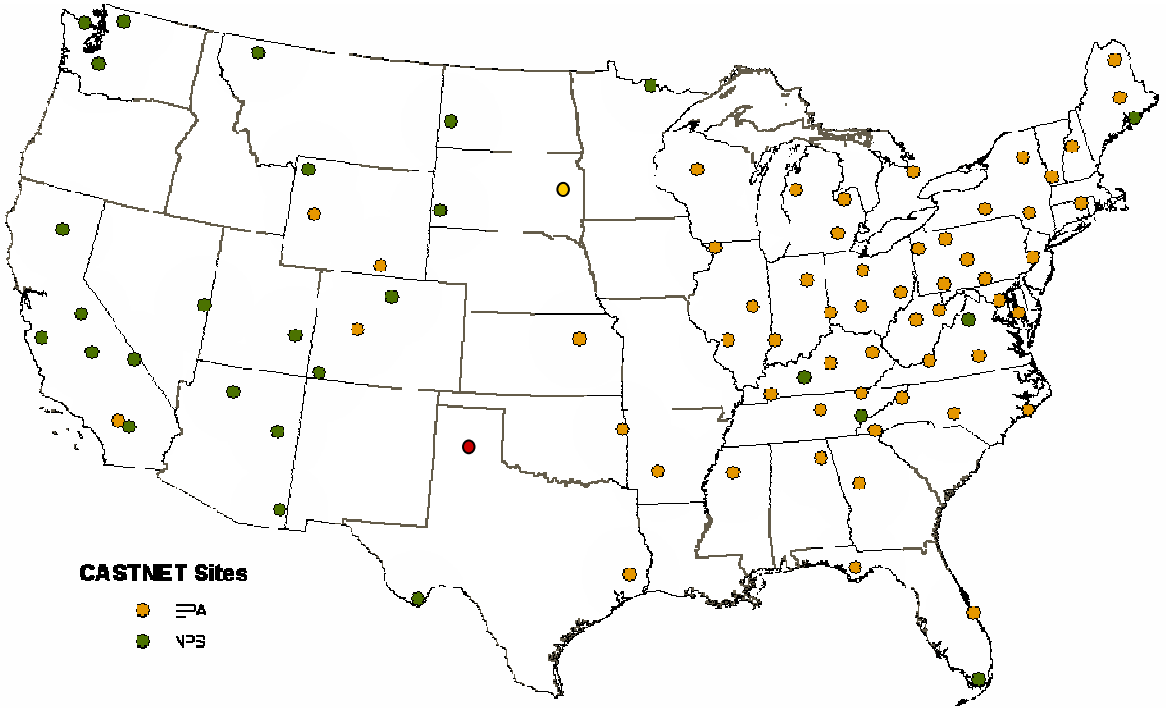
Dry sulfur deposition as percentage of total sulfur deposition (2001)

ENVIRONMENTAL PROTECTION AI

CLEAN AIR MARKET PROGRAMS

CASTNET Monitoring Program

- Operating since 1987
- Currently 87 sites in 40 states
- Weekly ambient concentrations of gaseous and particle species
- Continuous meteorology



- Sites are located in rural and often ecologically important locations, including 26 National Parks
- Dry deposition is estimated using an inferential model

CLEAN AIR MARKET PROGRAMS

CASTNET Measurements

Number of Sites	87 (+ 2 collocated)
Sampler	Filter pack - Teflon®, Nylon®, and Whatman®
Chemical analysis	Laboratory extraction and ion chromatography
Gaseous species	HNO_3, O_3, SO_2
Particle species	NO_3, NH_4, SO_4, Base cations
Meteorology	Temperature, precipitation, relative humidity, solar radiation, wind speed, wind direction
Land Use and Vegetation: (site observations)	Leaf Area Index (LAI) Percent green leaf out Vegetation Site Surveys
Sampling height	10 m
Sampling frequency	168 hours (1 week)
Sampling schedule	Tuesday to Tuesday

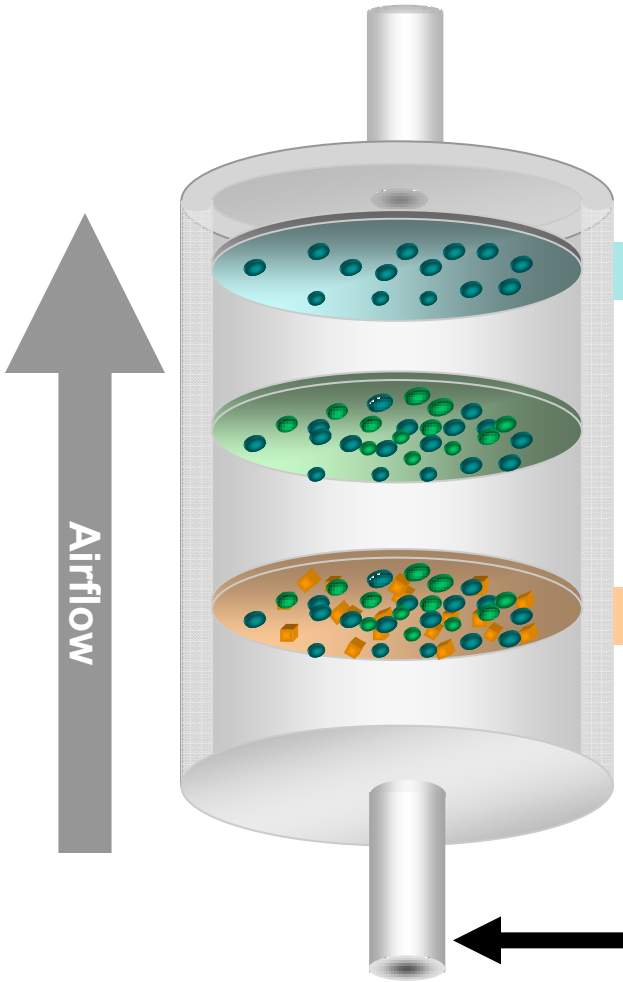
Ozone Measurements

- **All sites:**
  - Perform weekly zero/span precision checks
  - Are calibrated against NIST reference standards every 6 months
  - Annual external audit

- **NPS and Tribal sites comply with Part 58**
  - Results are entered into AQS
  - Are in process of certification for compliance determinations

- **EPA sites do not comply with Part 58**
  - Weekly zero/span and precision checks are not performed with external transfer standards
  - Cannot be used for compliance determinations

CASTNET 3-Stage Filterpack



Gas and particle concentrations in air are measured by filter packs and then used to estimate daily dry deposition

Whatman	Gaseous • SO_2
Nylon	Gaseous • HNO_3 • SO_2
Teflon	Particulates • SO_4^{2-} • NO_3^- • NH_4^+ • Ca, Na, Mg • Cl

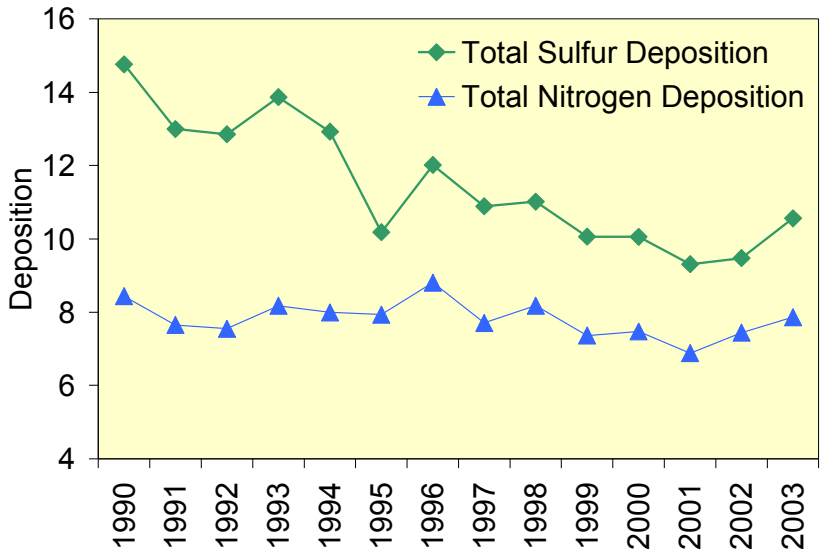
Filter packs are open-faced, with no size exclusion

- 20% of S and N deposition can be from coarse particles
- HNO_3 reacts with inlets

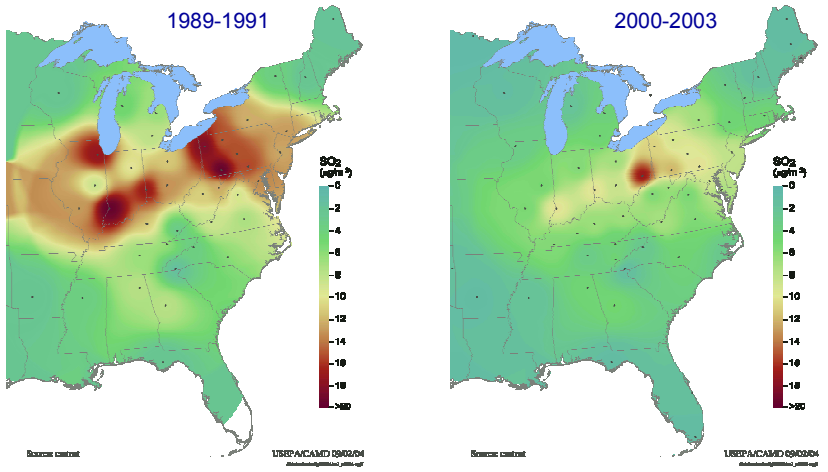
Accountability begins with consistency

CASTNET is designed to provide concrete accountability measures and indicators of environmental improvements

Trends in Dry and Wet Deposition

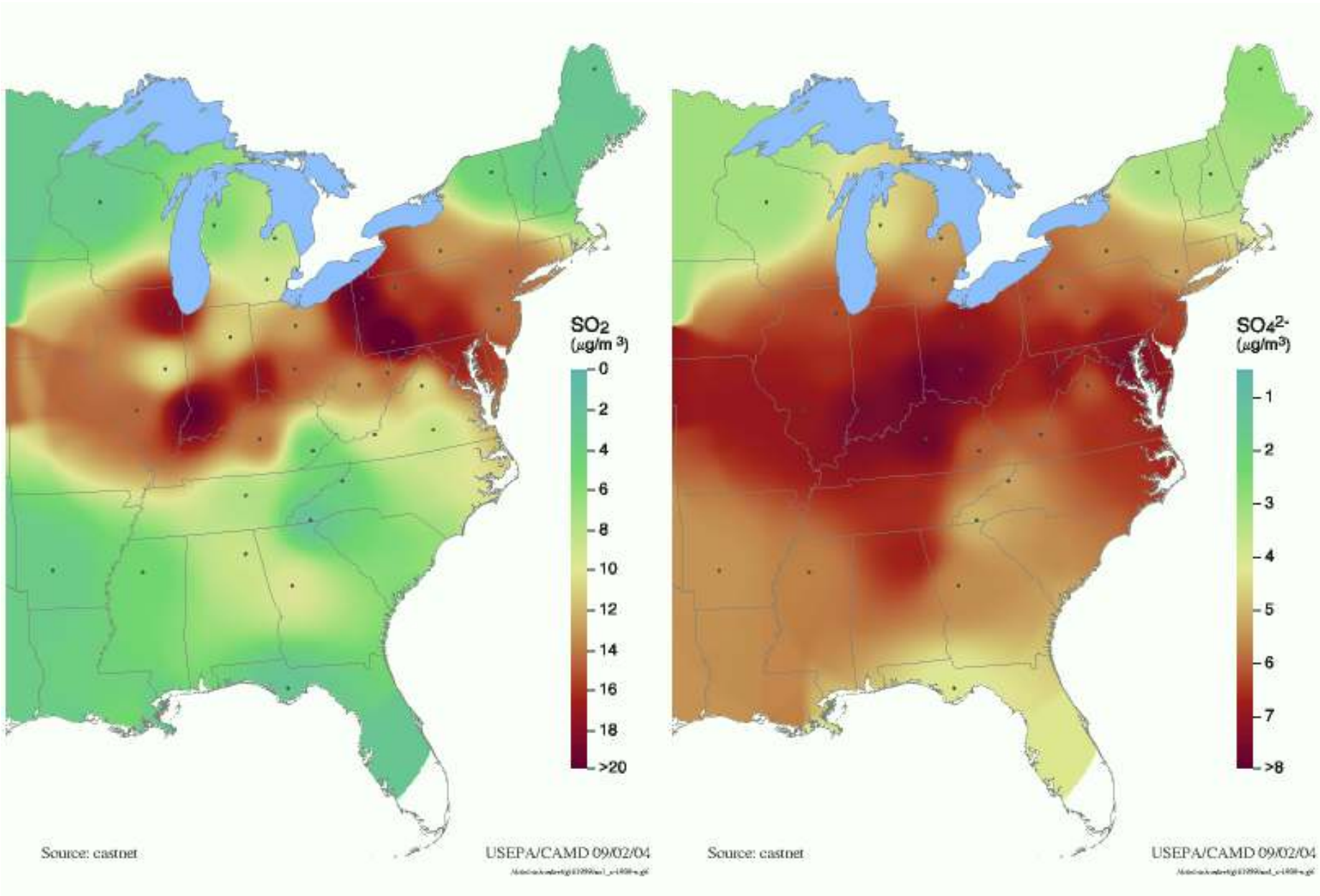


Trends in SO2 Concentrations

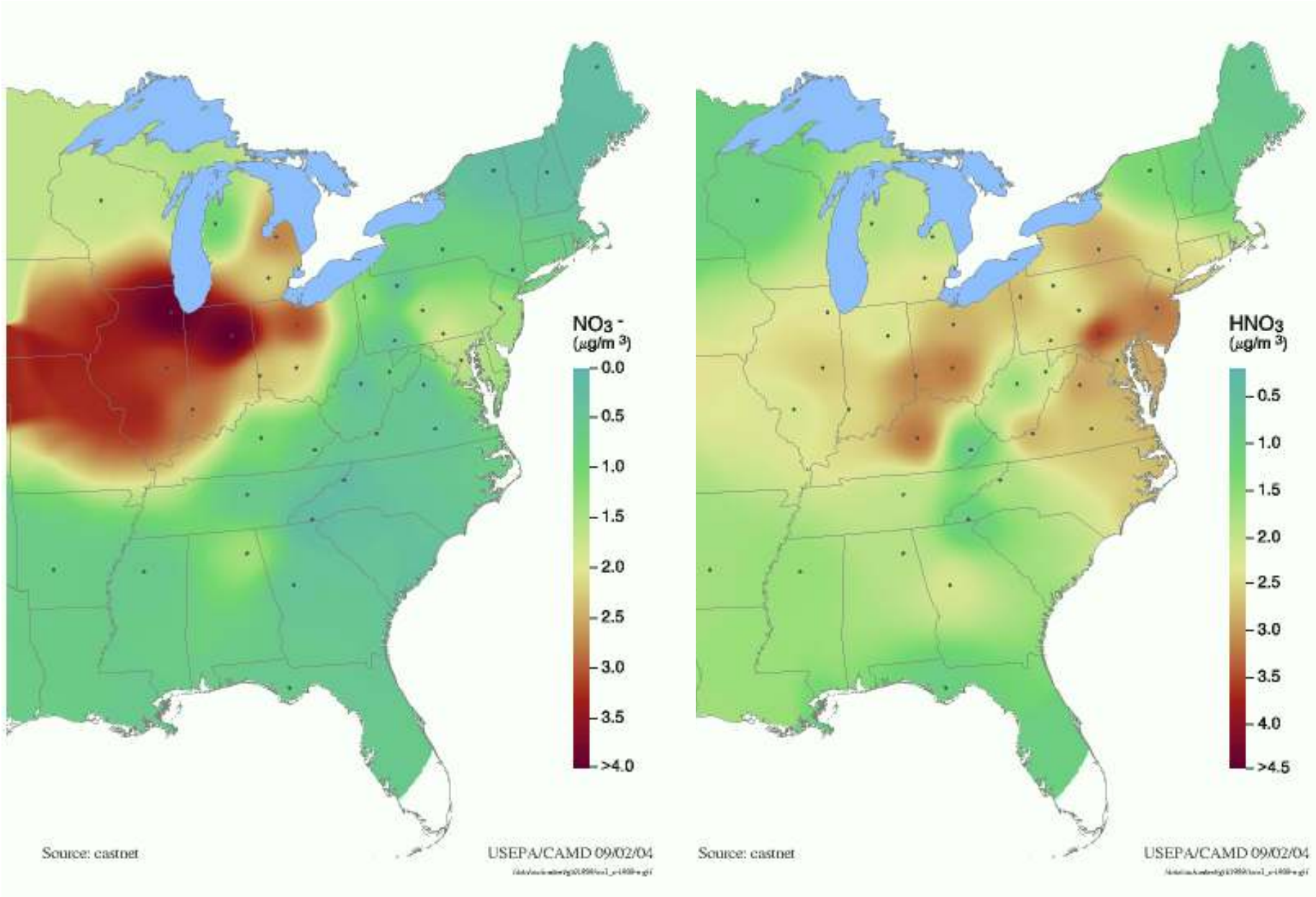


- Regionally representative
- Consistent methods
- Long-term operation
- Comprehensive quality assurance
- Network intercomparisons

SO_2 1989 SO_4


SO2
(µg/m 3)
0
2
4
6
8
10
12
14
16
18
>20
Source: castnet
USEPA/CAMD 09/02/04
SO4 2-
(µg/m3)
1
2
3
4
5
6
7
>8
Source: castnet
USEPA/CAMD 09/02/04

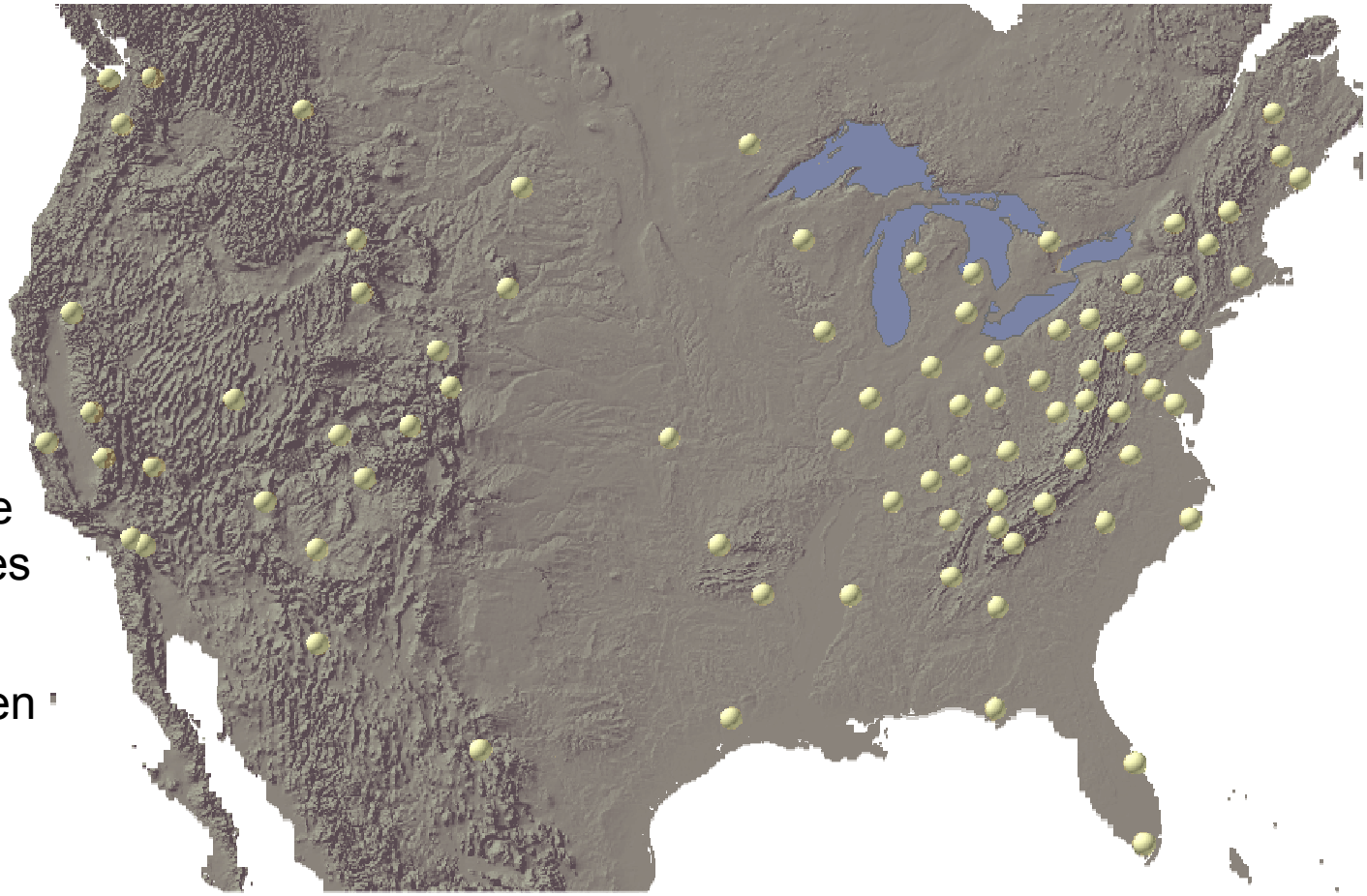
NO_3 1989 HNO_3



Regionally representative is important

CASTNET sites are located in rural areas and conform to specific siting criteria

- Regionally representative
- Minimal influence from local sources
- Minimized variability between sites



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Regionally representative is important

Case Study: WY Department of Environmental Quality has been studying the effects of energy development near the Jonah gas field.

- Similar topography
- 25 miles apart
- Are they redundant?
- What decisions can we make based on the data?

Slide 15

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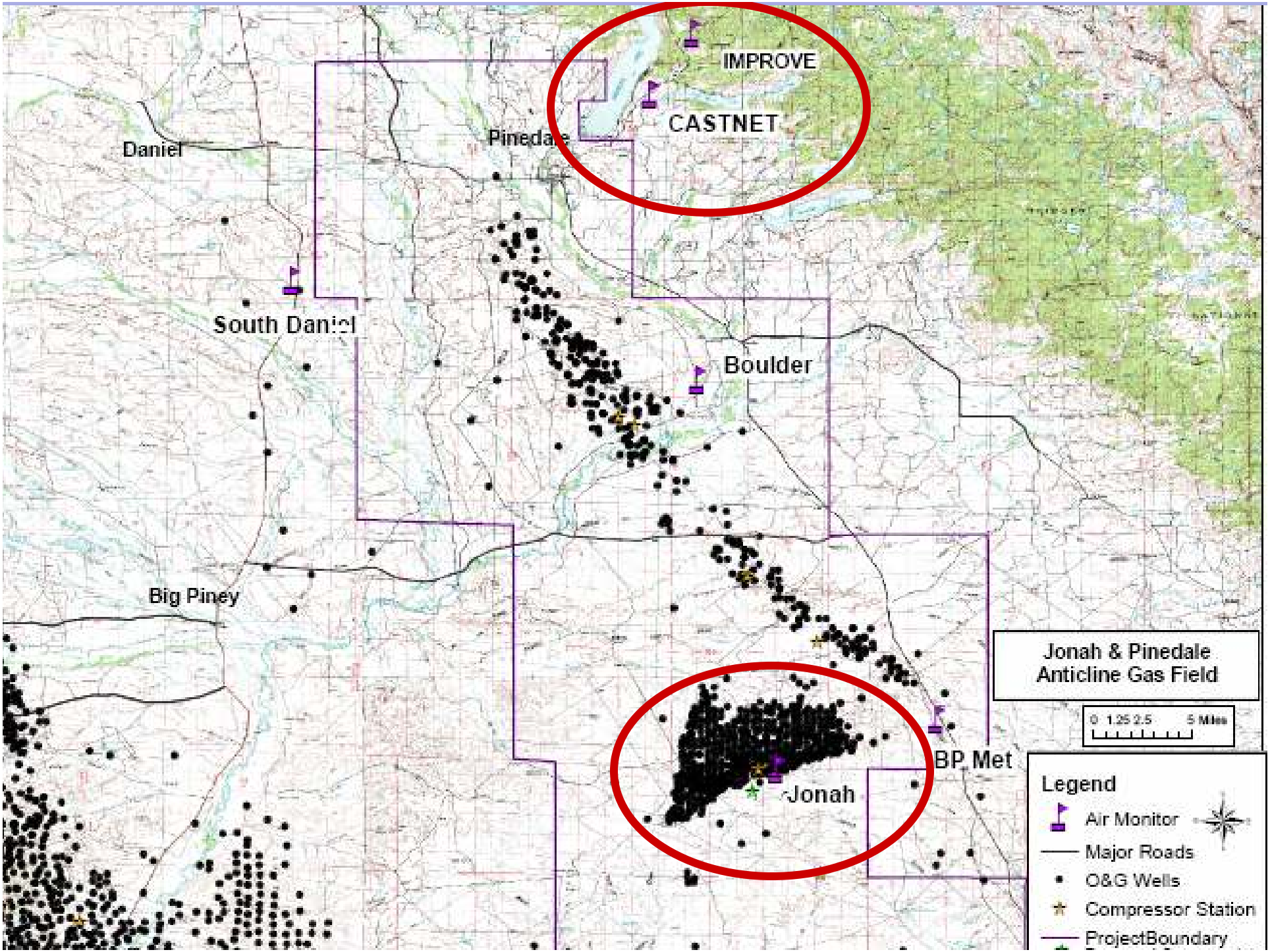
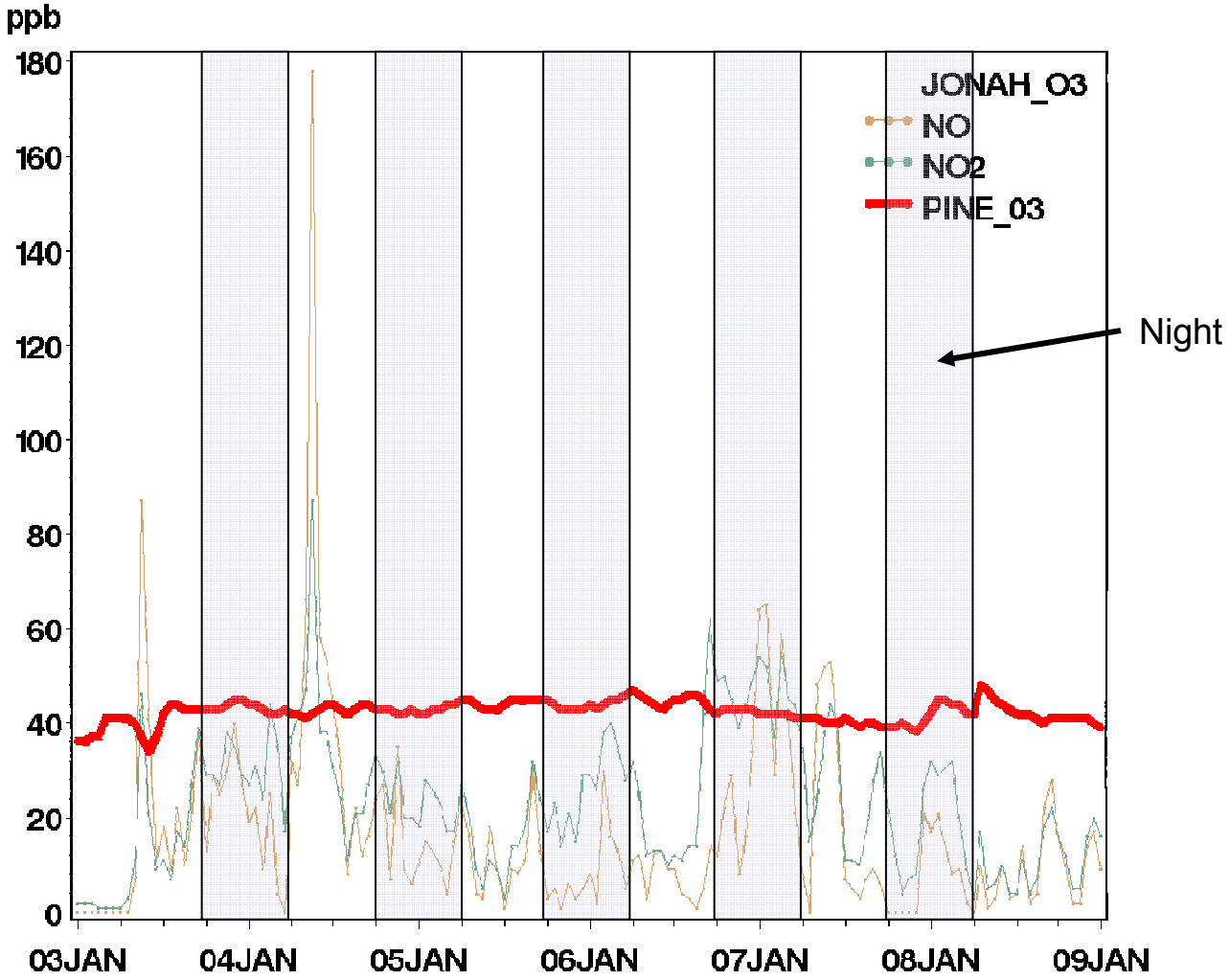
2 sites
identical topography
25 miles apart
What's representative?
What decisions can we make?
Are these sites redundant?
glear, 11/7/2006


IMPROVE
CASTNET
Daniel
Pinedale
South Daniel
Boulder
Big Piney
Jonah
BP Met
Jonah & Pinedale
Anticline Gas Field
0 1.25 2.5 5 Miles
Legend
Air Monitor
Major Roads
O&G Wells
Compressor Station
ProjectBoundary

Ozone Pinedale, WY

- Temperatures are < -10 C
- Little evidence of photolytic ozone production
- Gas fields have little effect, right?

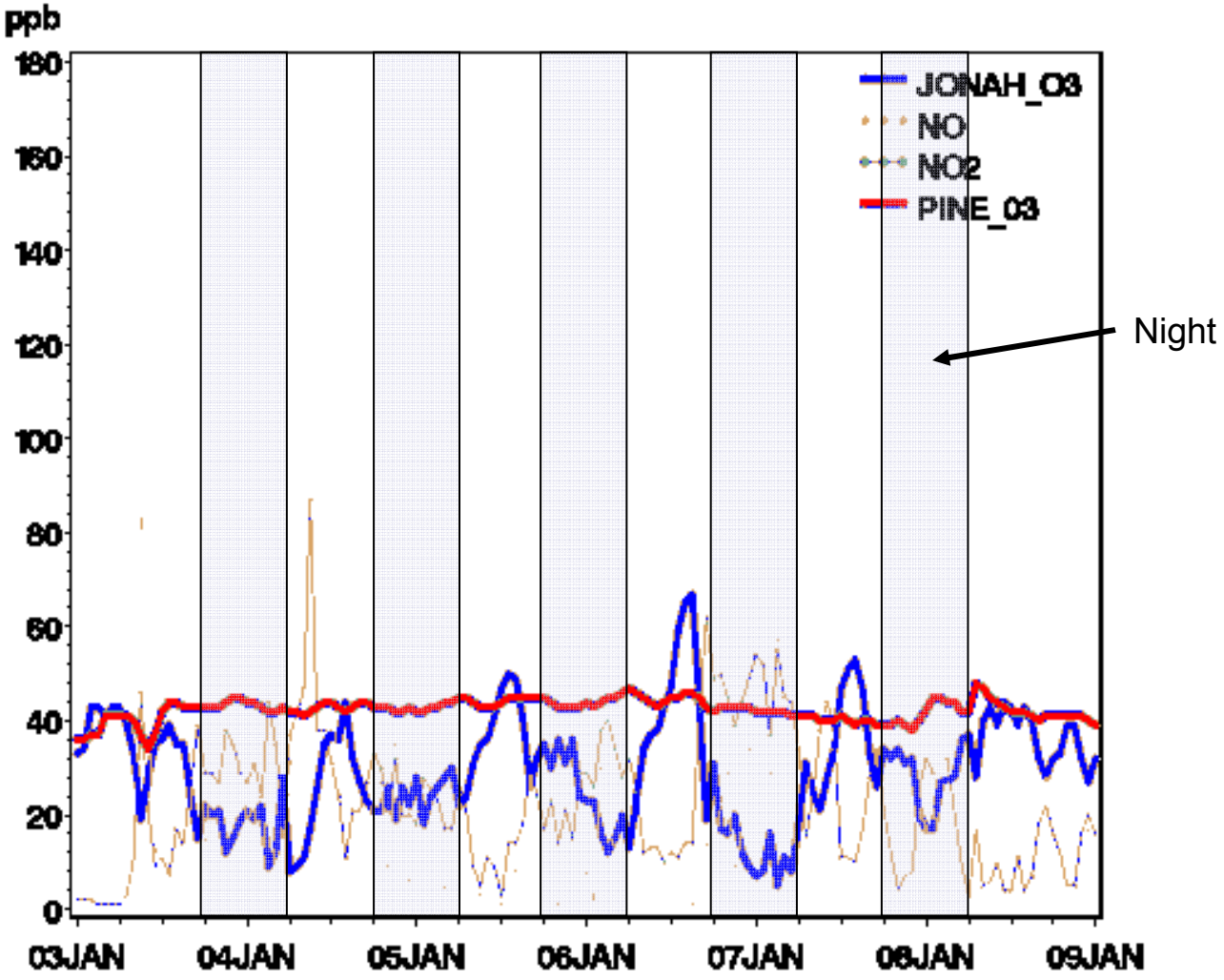


Data provided by WY DEQ

Ozone at Jonah and Pinedale

Local NOx emissions influence ozone concentrations at Jonah!

- Ozone is consumed through reaction with NO at night
- Photolytic production during the day
- Average concentration is about 60% of background levels



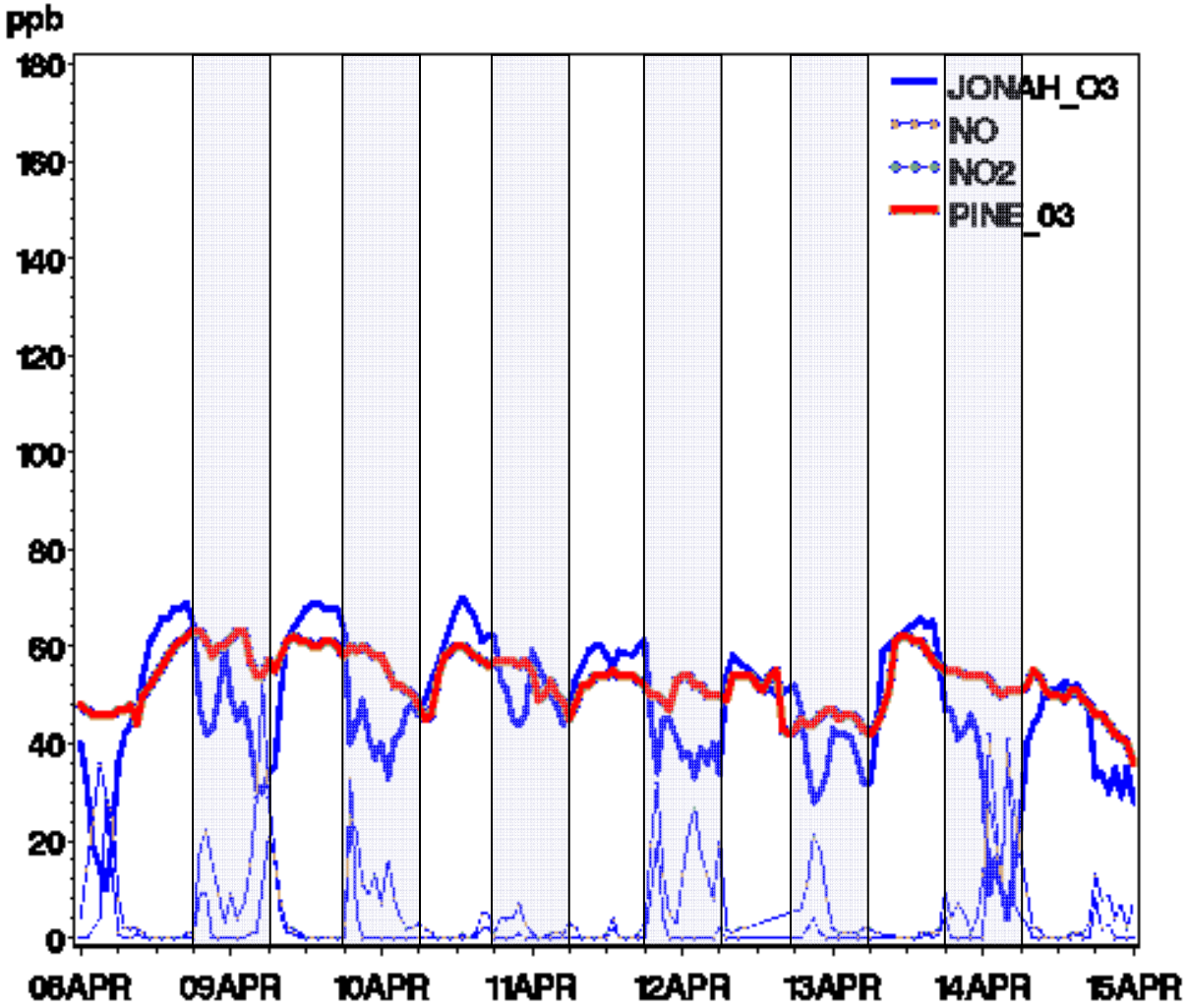
Data provided by WY DEQ

CLEAN AIR MARKET PROGRAMS

Ozone at Jonah and Pinedale

Local NOx emissions influence ozone concentrations at Jonah

- Ozone is consumed through reaction with NO at night
- Photolytic production during the day
- Average concentration is about 80% of background levels

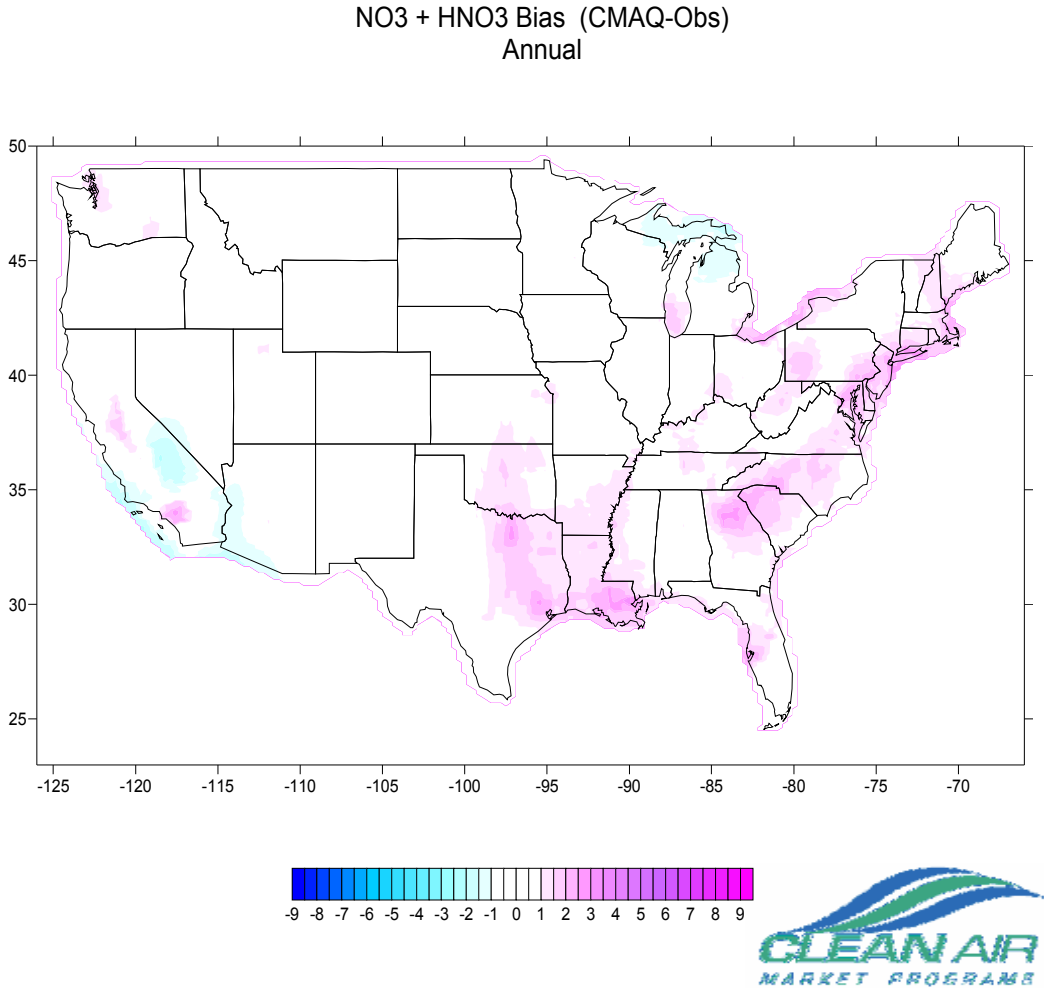


Data provided by WY DEQ

Model Validation/Development

CASTNET provides critical data to validate and improve air quality models, including CMAQ, REMSAD and RADM

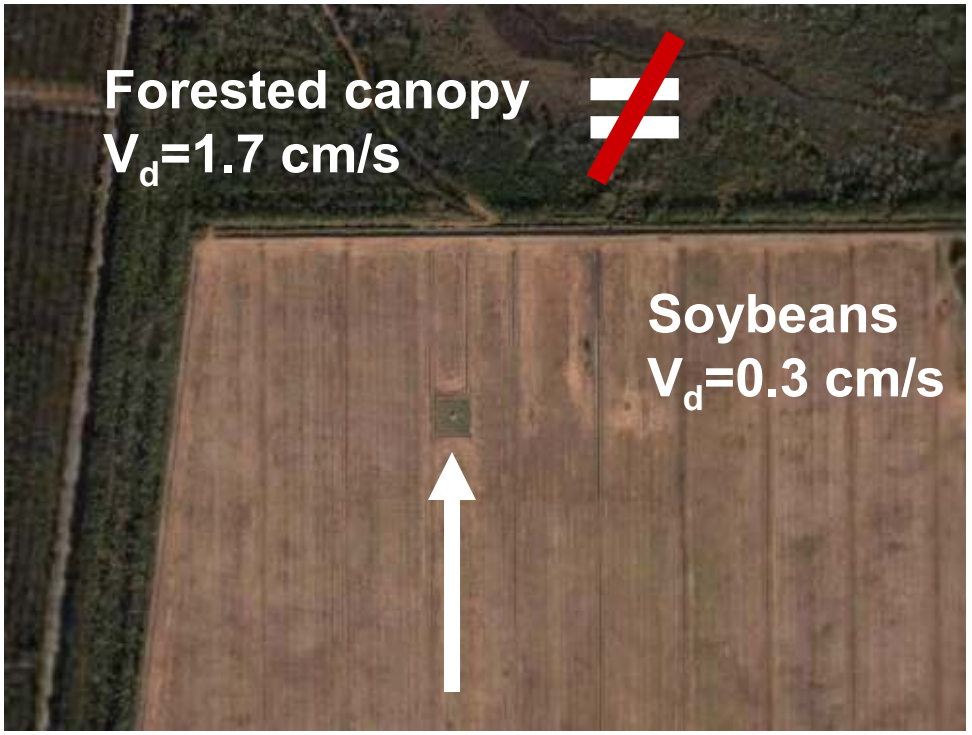
- Deposition is the primary removal mechanism of pollutants from the atmosphere
- If we don't get it right, the model gives biased results
- EPA makes decisions worth $10 Billion based on these model output



CLEAN AIR MARKET PROGRAMS

Estimating Dry Deposition Flux

- Flux is the product of air concentrations and modeled deposition velocity
  - $Flux_{(kg/ha)} = C_{(ug/m^3)} \times V_{d\ (cm/sec)}$
- Deposition velocities (V_d)
  - Surface phenomena
  - Not a weather phenomena
  - Valid only for point locations
  - No scientifically-valid method for interpolating data
  - Estimated using inferential model



Dry deposition velocity for HNO_3 at Beaufort, NC

Estimating Dry Deposition

CASTNET is currently using the Multi-layer Model (MLM)

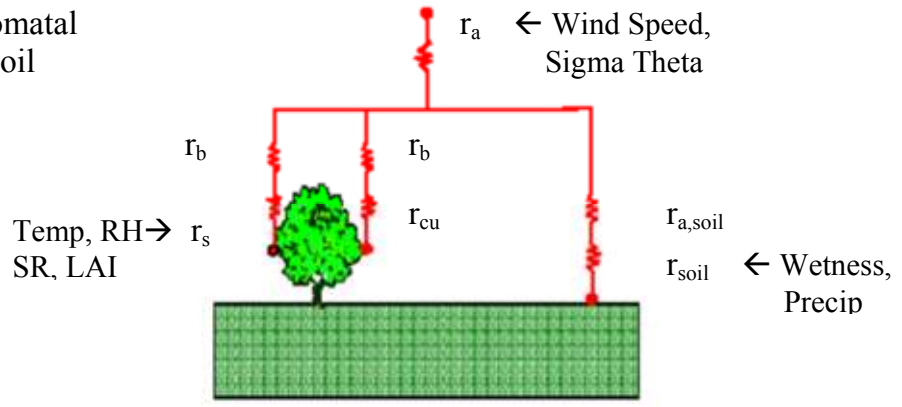
- Developed from the Big Leaf Model
- 20-layer model in which parameters are modified by the redistribution of heat, momentum, and pollutants.
- Meteorological input
- Site variables
  - Maximum Leaf Area Index (LAI)
  - Leaf out
  - Vegetative type

Multi-Layer Model (MLM)

$$\text{Flux} = C \times V_d$$

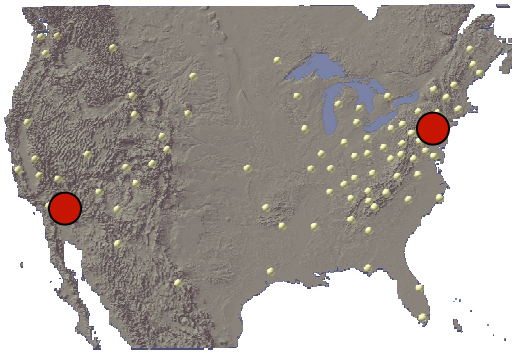
$$\frac{1}{V_d} = \frac{1}{\frac{1}{r_a + r_b} + \frac{1}{r_s + r_b} + \frac{1}{r_{a,soil} + r_{soil}}} + r_a$$

r_a = turbulence
$r_{a,soil}$ = turbulence near soil
r_b = thin layer at surface
r_{cut} = cuticular
r_s = stomatal
r_{soil} = soil



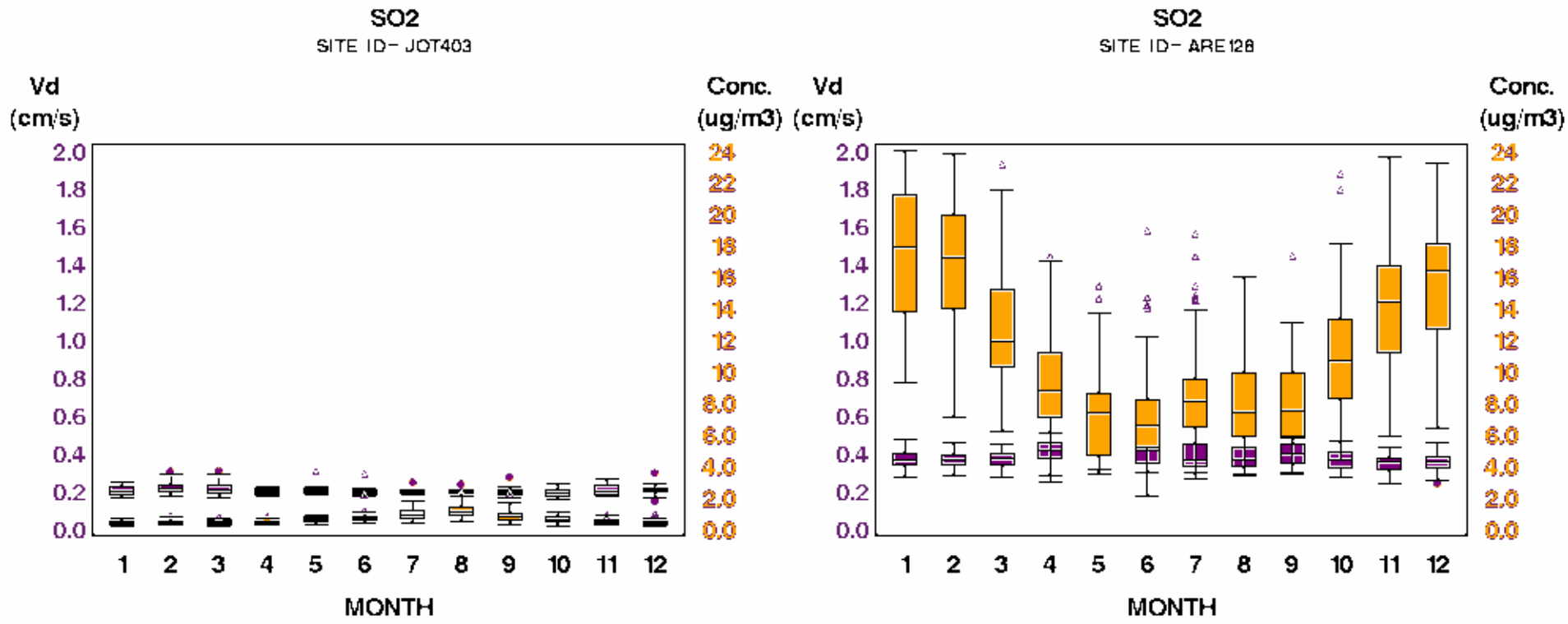
Significant variability temporally and geographically

Joshua Tree NP, CA

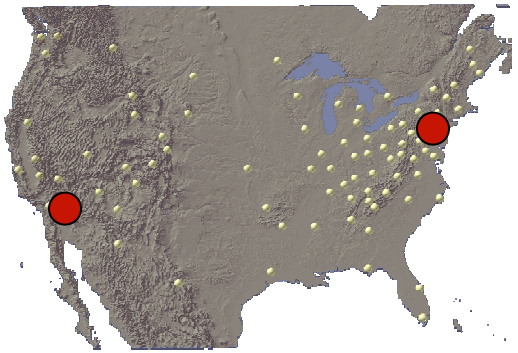


Arentsville, PA

Historical averages of deposition velocity and concentrations for SO_2

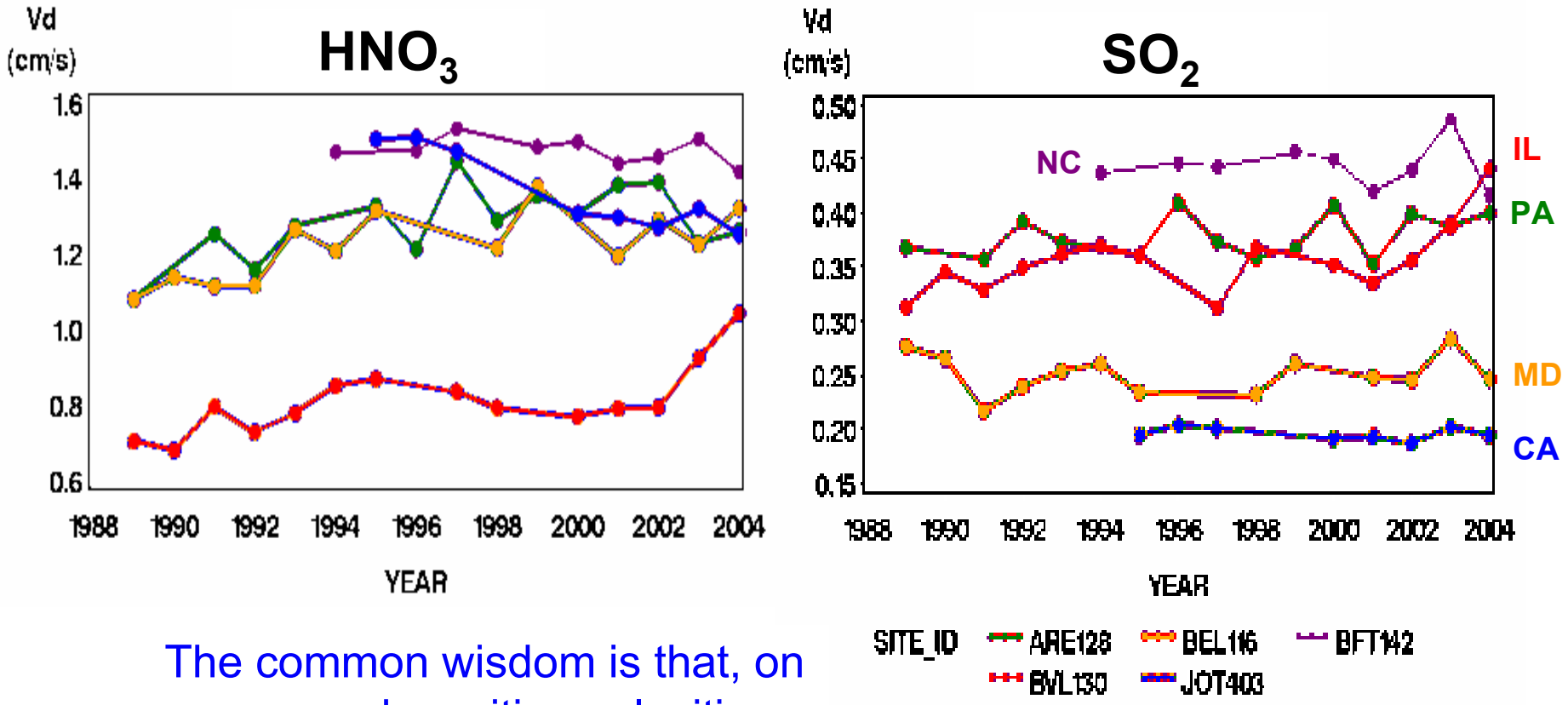


Joshua Tree NP, CA



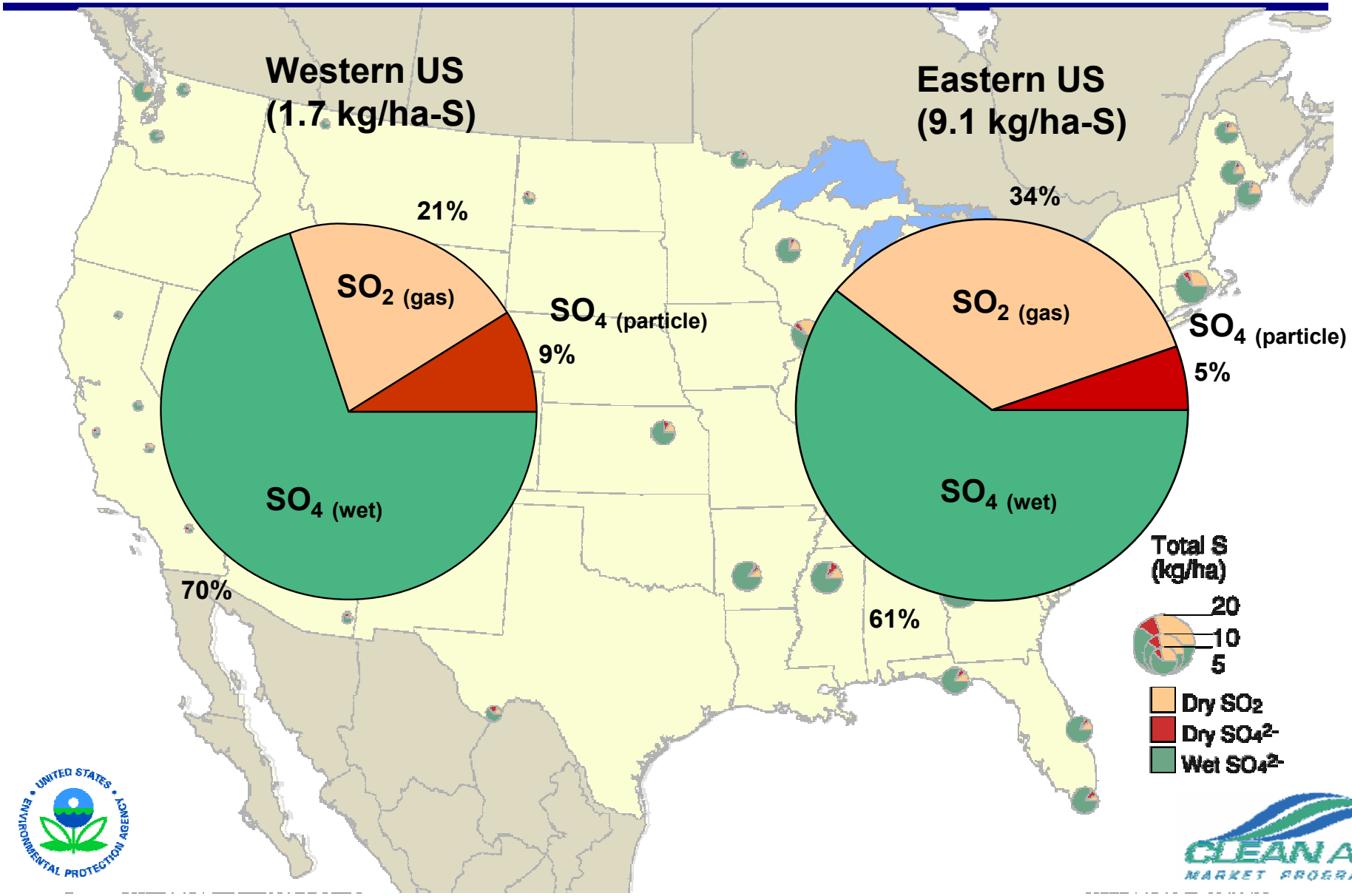
Arentsville, PA

Temporal Trends in Deposition Velocities

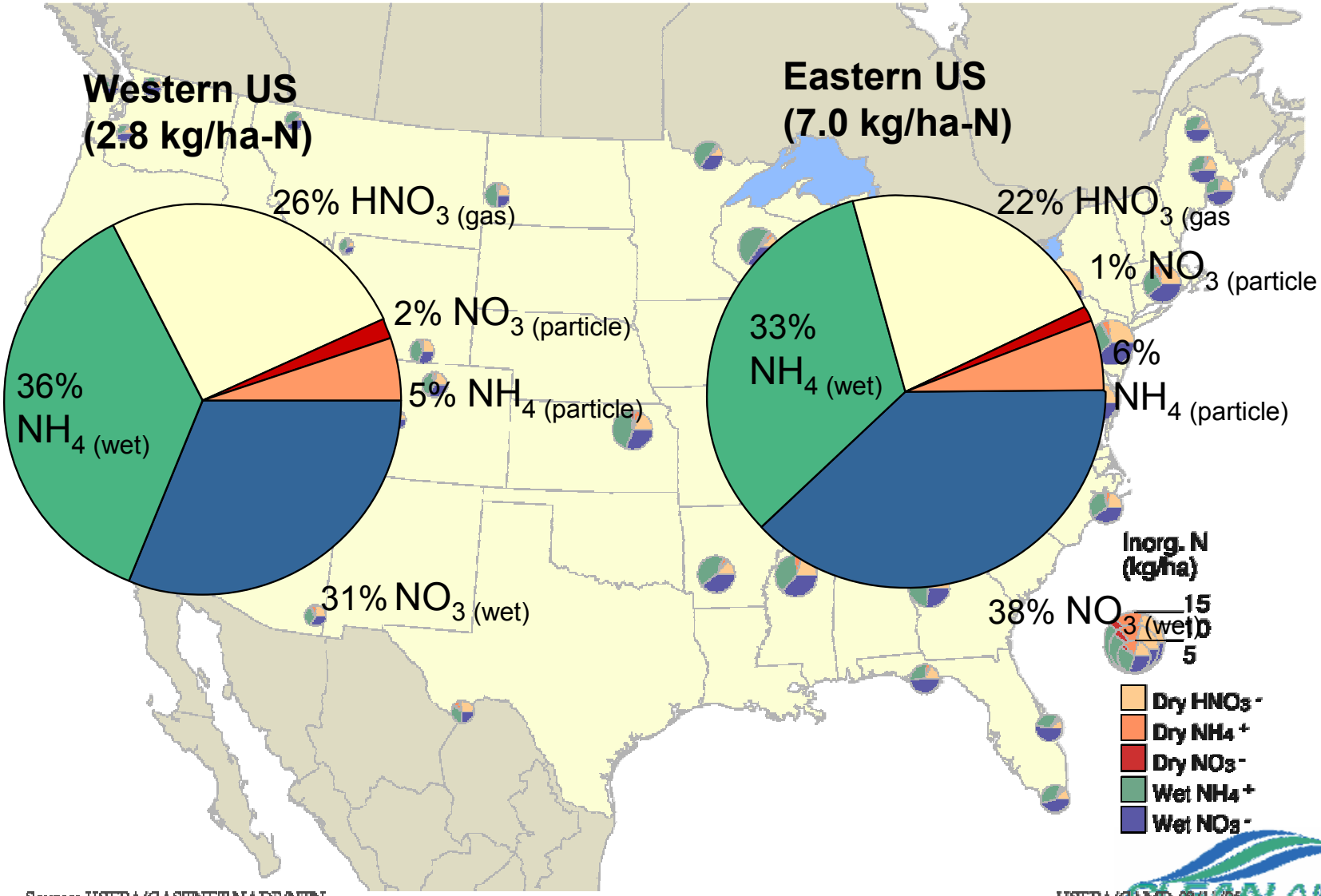


The common wisdom is that, on average, deposition velocities remain relatively constant

Total Sulfur Deposition for 2002 - 2004



Average Total Nitrogen Deposition for 2002 - 2004

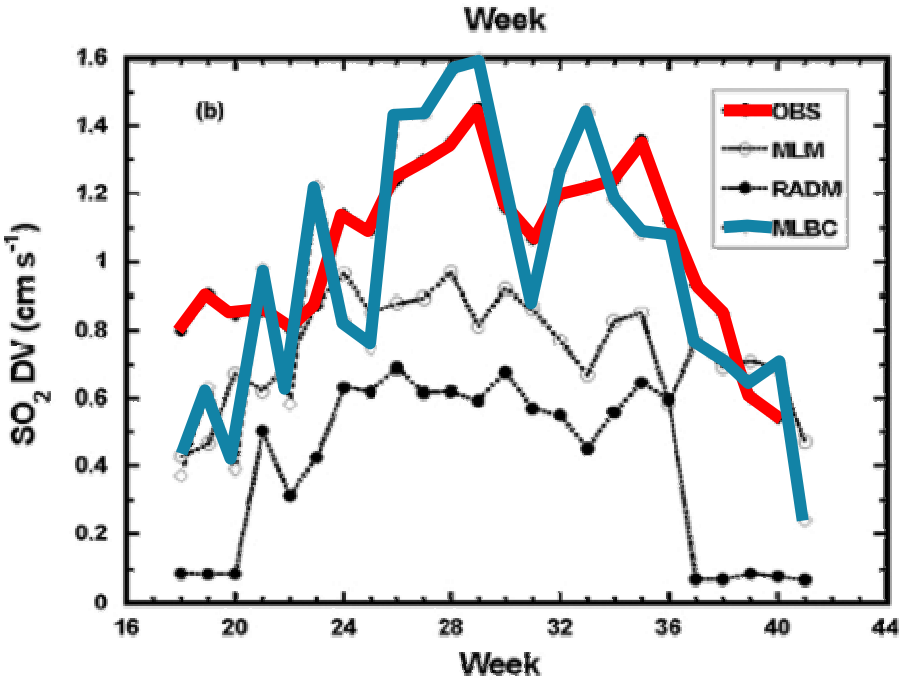


Multilayer Biochemical Model (MLBC)

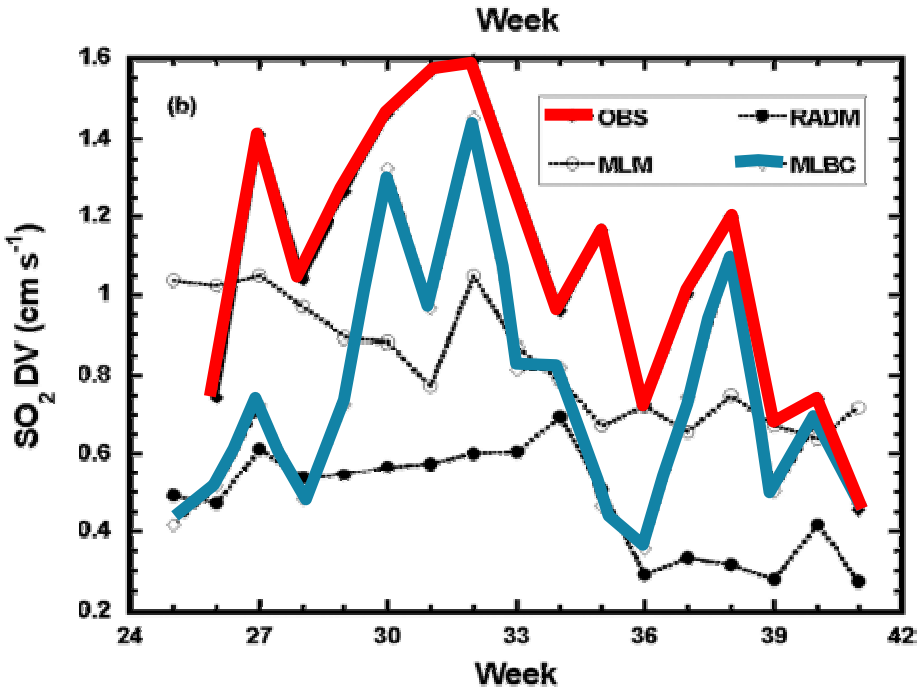
- CASTNET will begin testing MLBC in February 2007
- Based on Multilayer Model
- Adds biochemical plant growth module
  - Photosynthetically driven stomatal resistance (Berry-Farquhar approach)
  - Cuticular resistance based on membrane transport theory
  - Soil resistance and water stress revised from MLM
- Ammonia module
- More information at *Wu et al, JGR 108:4014, 2003*

Multilayer Biochemical Model (MLBC)

Improved performance over MLM in modeling observed deposition in time series and diurnal variations (*Wu et al, JGR 108:4014, 2003*)



Kane Forest, NY



Nashville, TN

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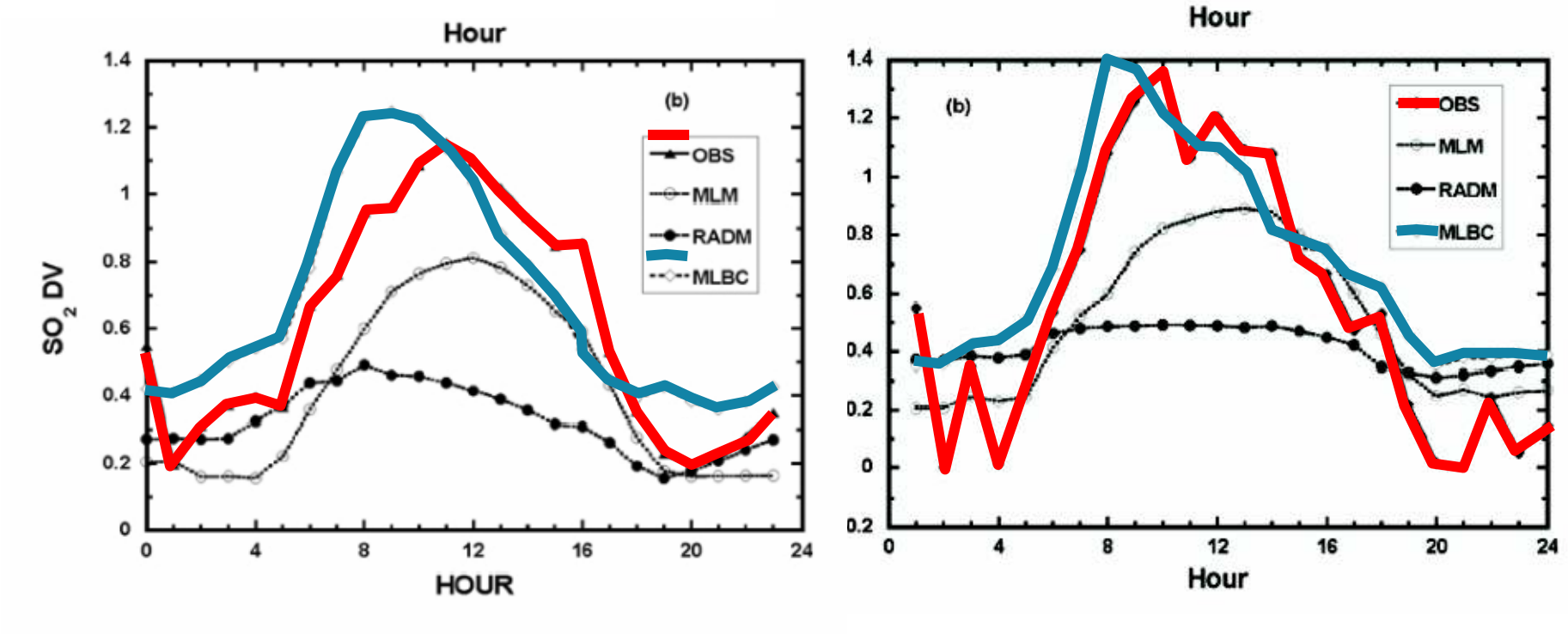


Kane Forest, NY

Nashville, TN

Expanding the capabilities of CASTNET

- **Add advanced instrumentation to ~30 sites**
- **Use multi-pollutant monitors to save on cost**
  - SO_2, HNO_3, HNO_2, O_3, **NH_3,**
  - SO_4, NO_3, NH_4, Base cations
  - **NO_y**
- **Seek local partners to complete NCORE**
- **Hourly resolution**
- **Real-time availability of data**
- **Use data fusion techniques to interpolate between sites**

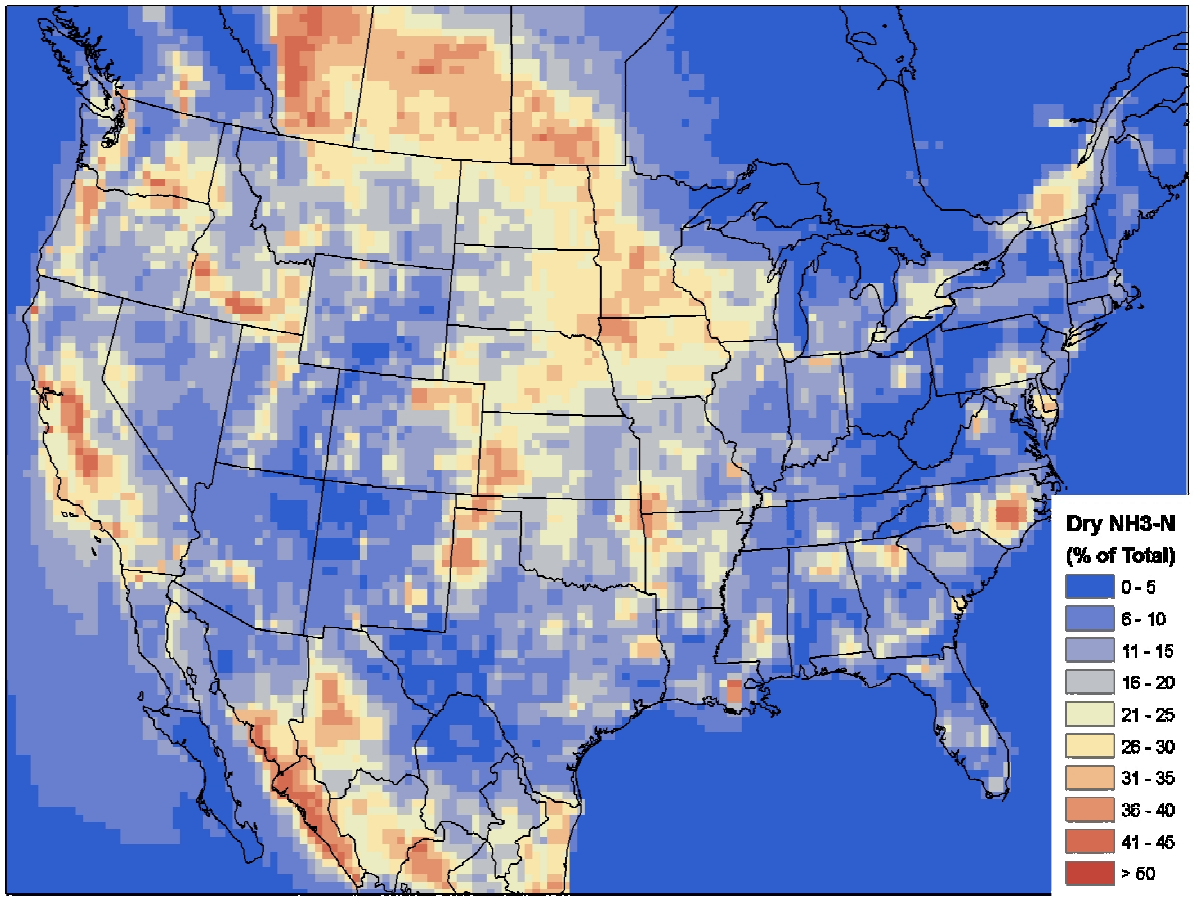
Multi-Pollutant Instrument Selected for Additional Testing

Sampler	MARGA
Chemical analysis	Ion Chromatography
Gaseous species	HNO_3, HNO_2, SO_2, NH_3
Particle species	NO_3, NH_4, SO_4, Base cations
Sampling height	4 m
Sampling frequency	1 hour (minimum is 20 min)
Sampling schedule	Continuous
Quality Assurance	Continuous internal standards
Data availability	1 hour (24 hours to Web)

MARGA (Monitoring Instrument for Aerosols and Gases)
-- Developed by ECN (Energy Research Center for the Netherlands) and APPLIKON, INC

Ammonia monitoring

- No network data avilable
- Working with Environment Canada to test passive samplers
- Efforts are underway to make passive and active ammonia measurements at CASTNET sites



CMAQ predicts over 30% of total N deposition is due to ammonia in some areas (2001)

The Bigger Picture

- Measuring air concentrations is only one aspect of the CASTNET mission
- Quantifying dry deposition is also important
- Understanding atmospheric chemistry and meteorology REALLY helps
- We still need to make sense of past and current CASTNET deposition estimates